MEMORANDUM REPORT ARLCD-MR-77006

FEASIBILITY OF USING FLUORESCENT MATERIALS IN PRODUCT ASSURANCE APPLICATIONS AND FOR LOCATING ADHESIVE BOND FRACTURES

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MARCH 1978

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Memorandum Report ARLCD-MR-77006
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER

4. TITLE *(and Subtitle)*: FEASIBILITY OF USING FLUORESCENT MATERIALS IN PRODUCT ASSURANCE APPLICATIONS AND FOR LOCATING ADHESIVE BOND FRACTURES

5. TYPE OF REPORT & PERIOD COVERED

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): Carolyn A. L. Westerdahl, J. Richard Hall

8. CONTRACT OR GRANT NUMBER(s): AMCMS Code 6121.05.11H8.4

9. PERFORMING ORGANIZATION NAME AND ADDRESS: Feltman Research Laboratory, Picatinny Arsenal, Dover, NJ 07801

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS: ARRADCOM, ATTN: DRDAR-TSS, Dover, NJ 07801

12. REPORT DATE: March 1978

13. NUMBER OF PAGES: 32

14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*: ARRADCOM, LCWSL, Applied Sciences Division (DRDAR-LCA), Dover, NJ 07801

15. SECURITY CLASS. *(of this report)*: Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release, distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Materials, fluorescent	Spectra, fluorescence
Adhesive bonding, process control	Failure, cohesive
Quality control	Failure, adhesive
Fracture, adhesive-bonded joints	Detection, UV

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

A number of adhesives, coatings, polymers, fluorescent pigments, brighteners, and solvents were surveyed to determine if they are fluorescent, and if so, which wavelengths of light excite them and at which wavelength they emit light. Practical uses of fluorescence are catalogued. The advantages of using fluorescent examination are shown and suggestions are made for its use in quality control applications and in investigating failed adhesive bonds.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

19. KEYWORDS (Continued)

4-chloro-7-nitrobenzofurazan (NBD chloride)
Adhesives
Coatings
Polymers
Pigments, fluorescent
Brighteners

ACKNOWLEDGMENTS

The authors are grateful to Mrs. M. C. Ross for supplying samples, J. R. Jarrell for providing equipment, and Dr. D. W. Levi for his valuable suggestions.

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INTRODUCTION

Automation of assembly lines and the increasing prevalence of 100% inspection make necessary the detection of adhesives, surface primers, and other materials at certain stations of the assembly line. For example, the presence of adhesive used as a bonding agent should be verified before the bonded components are assembled in the end item. On the other hand, adhesive accidentally dropped on a component should be detected and removed before final assembly. Because these materials are often colorless or of a noncontrasting color, direct detection is difficult and indirect methods, such as electric eye detection of falling drops or monitoring of the reservoir level, are used. Such methods are not completely satisfactory because they are indirect and only verify that the liquid is leaving the reservoir without indicating where it is going.

Fluorescent detection is one of the more promising methods of direct detection. If the material is naturally fluorescent there is no problem. If it is not, fluorescent dye may be added. It is then illuminated with an ultraviolet or black light source and the emitted visible light is detected visually or with instrumentation. The detectors for visible light are sensitive and inexpensive. With fiber optic guides available for the UV and visible regions, it is possible to detect a substance in a congested space or otherwise inaccessible position. Many polymers are naturally fluorescent so that their presence at the correct location in an item can be detected efficiently by fluorescence.

One of the big advantages of fluorescent detection is low background interference which results from the fact that the exciting illumination is often far removed in wavelength from the fluorescent light emitted by the substance. This method is also efficient for quick visual inspection, particularly if easily obtained UV filtering glasses are worn. In this way traces of adhesives remaining on broken bonded adherends can be seen. By scanning the surface for traces of adhesive it is possible to determine whether the fracture took place within the bulk of the adhesive (cohesive failure) or at the interface between the adhesive and the adherend (adhesive failure). One then knows whether to concentrate on surface treatment or on the physical properties of the adhesive to solve the adhesive failure problem.

This report is a survey of some of the common adhesives, coatings, polymeric solids, pigments, and solvents. The wavelengths of the exciting and emitted light are included, as well as an indication of strengths of peaks.

DISCUSSION AND RESULTS

Survey

The materials investigated included representatives of most of the common types of adhesives (Table 1), many of the common structural polymers (Table 2), a series of fluorescent pigments (Table 3), and some common solvents (Table 4). These materials were chosen to give a nucleus of information about common fluorescent materials so that the feasibility of using this method of quality control could be investigated conveniently. Many of these materials are naturally fluorescent or contain small amounts of fluorescent impurities. This fluorescence makes a tag which is suitable for following the location of the substance of interest. Trace amounts of fluorescent dyes and paint can be added to transparent substances to give an adequate response to UV light.

Fluorescence occurs when an electron in an atom or molecule is excited from a ground state to a higher electronic state by a photon. It loses some energy by a nonradiative transition, then decays back to the ground state. Because of the energy loss in the nonradiative transition (e.g., vibrational cascade), the energy of the emitted light is less than that of the exciting light, i.e., has a longer wavelength. The fact that the wavelengths of the exciting and emitted light can be widely different means that there is almost no interference between them and therefore there is a low background. Fluorescence spectroscopy is capable of good discrimination because only certain wavelengths will excite a molecule and when it is excited it will emit only certain wavelengths. This means that if one restricts the exciting light to a certain wavelength range and accepts only certain emitted wavelengths, only a small percentage of fluorescent compounds will be detected. This fact enables one to doubly discriminate against unwanted fluorescent substances and to be very specific in detecting the material of interest.

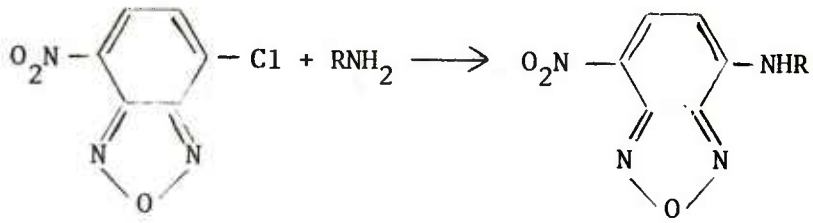
Practical applications have been made of the detection of fluorescent adhesive. The fluorescence of a black polyurethane rubber adhesive, PR 1520, has been used to detect its presence on a black neoprene substrate in the Lance system (Ref 1). Broken adhesive-bonded tensile specimens are routinely examined under UV light because many of the adhesives fluoresce and the small broken bits remaining on the faying surfaces are much more easily detected than under regular light. Besides the adhesives listed in Table 1, Tame 200, PB2 and EC 2214, used in the Durability Program (Ref 2, 3) have been used to study the distribution of adhesives on failed specimens. In the Rotating Band Program (Ref 4), EC 2290 was detected on Nylon 12.

In the AVSCOM Helicopter Repair Program (Ref 5), the presence of ADX 656.2 RT, Metlbond 1113, and EA 9628 on failed tensile specimens was detected. Fluorescent pigment has been added to Pettman cement (Ref 6) in an attempt to make it detectable on an assembly line. However, the high loading (50%) of iron oxide masks the added fluorescence. The amount of pigment which would be necessary for detection would make the cost of the cement excessive.

When using ultraviolet light, care must be taken to avoid overexposure of eyes and skin. In an automated line this is no problem and in a manual situation, opaque gloves and specially tinted glasses provide adequate protection.

Fluorescence Labeling of Polymers Containing Amino Groups

The use of NBD chloride (4-chloro-7-nitrobenzo-2-oxa-1,3-diazole) to detect and determine amino acids, peptides and other compounds containing amino groups has been described (Ref 7 through 10) on the basis of the fluorescent properties of the reaction products. The method consists of treating the amino compound with NBD chloride (also known as 4-chloro-7-nitrobenzofurazan) in dilute solution for a short time. The NBD chloride is nonfluorescent; the N-derivatives are strongly fluorescent. NBD chloride also reacts with -SH and -OH groups to produce derivatives which, although fluorescent, are less stongly so than those of amino compounds.



To test the feasibility of introducing fluorescent groups into the structures of nonfluorescent polymers containing amino groups, a "soluble" nylon was treated with NBD chloride in 80/20 ethanol/water. The nylon, Elvamid 8061 (DuPont), is a 6-6 nylon partially substituted with methoxymethyl groups. The solution showed strong fluorescence at 538 nm upon excitation at 415 nm. Solutions of NBD chloride in methanol or 80/20 ethanol/water also showed fluorescence in the same region, but much weaker and the excitation peak was at 469 nm.

In an earlier experiment, a piece of 6-12 nylon of a suitable shape for insertion into the spectrophotofluorometer was immersed in a 1% solution of NBD chloride for 1½ hours and rinsed. It exhibited

strong fluorescence at 520 nm; excitation, at about 460 nm. The NBD chloride solution was not fluorescent. (NBD chloride solutions prepared later did show some fluorescence. This appeared to be due either to slight contamination with amino vapors in the laboratory air or a slow reaction with -OH groups.) Untreated 6-12 nylon showed little or no fluorescence over the entire range.

The foregoing demonstrates the potential usefulness of NBD chloride as a fluorometric reagent for nylons and N-containing polymers. However, one of the investigators developed a rash from handling NBD chloride, indicating the need for care in the use of this compound.

EXPERIMENTAL

Materials

Solvents:

Styrene, stabilized, reagent grade.
2-methoxyethanol, scintillation grade.
Acetone, practical grade.
Isopropyl alcohol, reagent grade.
Heptane, chromatoquality grade.
Toluene, tech grade.
Ethanol, absolute, reagent grade.
Methanol, reagent grade.

Polymers:

Poly(4-methyl-1-pentene)	TPX, ICI America, Inc
Poly(vinyl fluoride)	Tedlar, 200-SG40-TR, E. I. du Pont de Nemours and Company, Wilmington, DE
Poly(oxymethylene)	Celcon, M90-01, injection-molding grade (MIL-A-50414), Celanese Corp
Nylon 6	Capran 77C, Allied Chemical Corp
Nylon 66	Almac Plastics, Long Island City, NY

Poly(ethylene terephthalate)	Mylar D, cartography grade, E. I. de Pont de Nemours and Company, Wilmington, DE
Cellulose acetate butyrate film	Almac Plastics, Long Island City, NY
Polycarbonate film	Lexan 8070-112, General Electric
Polyethylene fluff	6050, Phillips Petroleum, Bartlesville, OK
Polypropylene film	Dow 201, Dow Chemical, Midland, MI
Nylon 12	Rilsan Industrial Inc, Birdsboro, PA
Nylon 6-12	E. I. du Pont de Nemours, Wilmington, DE
Nylon 11	Rilsan Industrial Inc, Birdsboro, PA
Poly(chlorotrifluoro-ethylene)	Kel-F, Adam Spence, Edison, NJ
Poly(vinylidene) co-polymer	Saran F-310 powder, Dow Chemical, Midland, MI

Adhesives:

Epon 828	Epoxy resin, diglycidyl ether of bisphenol A, Miller-Stephenson Chem Co, Inc, Danbury, CT
Accrabond 7521	Styrene monomer polyester, Accrabond, Memphis, TN
PRC 1660	Polyurethane elastomer with MEK (Parts A and B), Products Research & Chemical Corp, Burbank, CA

V-40	Polyamide resin, Miller-Stephenson Chem Co, Inc, Danbury, CT
EC 3549-B	3M Company, St Paul, MN
EC 2216-A, B	Epoxy adhesive: Part A, hardener-modified amine. Part B, base epoxy resin, 3M Company, St Paul, MN
RTV 118	Poly(dimethyl siloxane), Dow Corning Corp, Midland, MI
Flexcraft 1256-2	Synthetic resins in ketones and esters, Flexcraft Industries, Newark, NJ
Laminac 4116	Styrene monomer, American Cyanamid
Loctite 317	Anaerobic modified acrylic, Loctite Corporation, Newington, CT
Loctite 271	Anaerobic dimethacrylate, Loctite Corp, Newington, CT
Vibratite VC3	Nylok-Detroit, Troy, MI
Pettman Cement Type A	50% iron oxide, 20% ethyl alcohol, 12% pine tar, 18% shellac, Bradshaw Praeger & Co, Chicago, IL
Scotch Weld 2214	Aluminum-filled one-part-modified epoxy adhesive, 3M Company, St Paul, MN
Scotch Grip 1357	Polychloroprene in solvent, 3M Company, St Paul, MN
ADX 656.2	Supported epoxy, Hysol Division, Dexter Corp, Pittsburgh, CA

PL 717B	Supported epoxy, B. F. Goodrich General Products Company, Akron, OH
Metlbond 1113	Supported epoxy, Warmco Materials Inc, Costa Mesa, CA
EA 9628	Supported epoxy, Hysol Division, Dexter Corp, Pittsburgh, CA
Loctite 308	Anaerobic polyacrylate, Loctite Corporation, Newington, CT
Alfa 841	Aliphatic elastomeric polyurethane lacquer, Baker Castor Oil Co, Bayonne, NJ
Acryloid E 48-N 50/0	Acrylic resin, Rohm & Haas, Philadelphia, PA
EC 870	Oil resistant synthetic elastomer in toluol, 3M Company, St Paul, MN
Tame 200	Acrylic, B. F. Goodrich General Products Company, Akron, OH
EC 2214	Epoxy, 3M Company, St Paul, MN
PR 1520	Black polyurethane rubber, Products Research & Chemical Corp, Gloucester City, NJ
EC 833	Oil soluble elastomer in petroleum naphtha, 3M Company, St Paul, MN
LP 2	Polymer of bis(ethylene-oxy)-methane containing disulfide linkages, terminated with reactive thiol groups, Thiokol, Trenton, NJ

EC 1099	Nitrile rubber in ketone, 3M Company, St Paul, MN
Laminac 4134	Modified styrene, American Cyanamid Company, Wallingford, CT
Cascophen RS 216	Resorcinol in alcohol water, Borden Chemical, NY, NY
Penacolite	37% formaldehyde - water

Fluorescent Pigments:

B 3556	Blue, Lawter Chemicals, Inc, Chicago, IL
B 3515	Gold yellow, Lawter Chemicals, Inc, Chicago, IL
B 3513	Red orange, Lawter Chemicals, Inc, Chicago, IL
B 3545	Green, Lawter Chemicals, Inc, Chicago, IL
B 3530	Cerise, Lawter Chemicals, Inc, Chicago, IL
B 3522	Pink, Lawter Chemicals, Inc, Chicago, IL
Uvitex OB	Fluorescent whitener, Ciba-Geigy Corp, Ardsley, NY
Tinopal PCRP	Fluorescent whitening agent, Ciba-Geigy Corp, Ardsley, NY
NBD Chloride	4-chloro-7-nitrobenzofurazan M.P. 97-99°C, Aldrich Chemical Company, Milwaukee, WI

Instruments

The spectrophotofluorometer, an Aminco Bowman instrument, consists of an optical unit, a photomultiplier microphotometer, an X-Y recorder, and accessory components. The optical unit includes a Xenon lamp, two monochrometers, slit holders, a cell compartment, and a photomultiplier housing. Light from the Xenon lamp is dispersed by the initial grating monochrometer into monochromatic radiation incident on the sample. The fluorescent radiation given off by the sample is dispersed by another grating into monochromatic radiation incident on the photomultiplier. The light produces a weak electrical signal which is fed to the photometer where it is amplified. This signal is sent to the recorder.

The gratings are operated by motor-driven cams coupled with graduated discs for visual observation and manual adjustment of wavelengths. One grating can be driven at a time. A potentiometer coupled to a grating supplies wavelength information to the recorder in the form of a DC voltage. Thus, with the exciting wavelength set, a graph of emission intensity versus wavelength may be obtained or, if the emission wavelength is set, a graph of intensity versus excitation wavelength is recorded.

The sample may be either liquid or solid. Liquids are usually placed in a 10 mm pathlength cuvette with four polished sides. The fluorescent emission is detected at 90° to the path of the exciting light. In a nonturbid solution, there is essentially no background from this light. There are also cylindrical microtubes with interior diameters of 2 mm. These can be used with strongly absorbing solutions, but tend to have more of a scattering background.

Finely divided solids can be used in either the cuvettes or tubes with some success. Strips or films can be placed in a special holder in which a mirror placed to the side of the exciting beam directs the light reflected from the sample into the emission monochrometer. This holder may also be used for opaque liquids. With this holder there is a large amount of background from the exciting light.

Slits can be inserted in the incoming beam and the emitted beam and before the photomultiplier to control the amount of light in the system and the bandwidth of the light.

The cuvettes are cleaned after each use by boiling them in concentrated nitric acid to eliminate any carryover of fluorescences.

Sample Handling

In running a sample, the sample was put into the cuvette which in turn was placed in the holder. A set of slits was selected, usually wide ones for the initial scans, and the microphotometer set to a moderate value. The excitation wavelength was set to 200 nm and the emission spectrum was run. If necessary, the sensitivity of the microphotometer was increased and the spectrum rerun. Then the excitation wavelength was increased to 250 nm and an emission spectrum was run. The excitation wavelength was increased in steps of 50 nm and an emission spectrum run for each. If there were any emission peaks, the emission wavelength was set on these and an excitation spectrum run. This was done for each emission peak. The spectra could be refined by using narrower slits as long as there was enough light.

Strongly absorbing substances were sometimes diluted with a non-absorbing solvent if a suitable one could be found. Several common solvents have large portions of their spectra free of absorption or emission peaks.

CONCLUSIONS

The use of UV light to excite fluorescence and thereby detect the presence of materials in their correct place on an assembly line is feasible and should be investigated when setting up 100% inspected criteria. Many organic materials are naturally fluorescent and most of the others can accept the presence of small amounts of a fluorescent pigment or label.

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Table 1

Fluorescence spectra of adhesives*

Adhesive	Excitation wavelength, nm (Set)	Emission wavelength, nm	Excitation wavelength (observed) nm
Epon 828		410	360
		460	385
	≤ 300	375-475 (VS)	
Accrabond 7521		510	388 (W)
	330	440	375 (S)
	385	455 (S)	
	430	486 (S)	385 (S)
		470	385 (S)
PRC 1660-L-A	430-510	490-600 (S)	
		550	465 (S)
L-B	220-240	350-520 (VS)	
	260-300	325-480 (VS) 630 (M)	
		325	297 (M)
		380	330 (VS)
		470	440 (S), 360 (M)
EC 3549B	≤ 360	590 (VW)	
	240-300	350 (W)	
	200-360	425-520 (M)	
		400	300 (W)
EC 2216A	400	460 (VS)	
	240-400	450-500 (W)	
		460	400 + (W)
		500	410-470 (M)
V-40	≥ 200	510 (VS)	450 (VS)
EC 2216B		370	330 (VS)
		400	340 (VS)
		430	355 (VS)
		460	375 (VS)
		490	387 (S)
		520	493 (M)
		550	400 (W)
	≥ 200	350-450 (VS)	
	440-460	500 (W)	

Table 1 (Continued)

Adhesive	Excitation wavelength, nm (Set)	Emission wavelength, nm	Excitation wavelength (observed) nm
RTV 118	200-280	325-425 (W)	
		320	None
		370	None
Flexcraft 1256-2	200-300	325-375 (M)	
		332	None
Laminac 4116	300-340	370 (VS)	
	320-400	430 (VS)	
		440	367 (VS)
Loctite 317 (amber)	320+	475 (VS)	
		475	420 (S)
Loctite 271 (red) microcell	--	--	
	300-360	460 (VS)	
	300	450	355 (VS)
Vibratite VC 3		600	350;470+ (W)
	200-250	600 (VS)	
Pettman Cement Lot 2586	200-400	350-550 (W)	
Scotch Weld 2214	240-280	305 (S)	
		200	None
Scotch Grip 1357	200-510	None	
EC 2290 on Nylon 11	200-350	365 to 430 (S)	
		365	310 (VW)
		450	360 (W)
		510	380 (W)
EC 2290 on Nylon 12	250-340	365 (W)	
	280-360	440 (W)	
A1413B on Nylon 11	--	--	
A1413B on Nylon 12	350-400	440 (S)	

Table 1 (Continued)

Adhesive	Excitation wavelength, nm (Set)	Emission wavelength, nm	Excitation wavelength (observed) nm
ADX 6562 RT	250-350	330-400 (M)	
		350-500	None
PL 717B	--	--	
Metlbond 1113	250-350	390-460 (M)	
		420	275, 320 (W)
		430	275, 335 (W)
EA 9628	200-350	335-470 (S)	
		350	No Sep Peak
		400-450	320-60 (W)
		500	385 (M)
Alfa 841	200-300	400-500 (W)	
	200-360	360-500 (S)	
		550	400 (W)
		510	380 (M)
		450	358 (W)
		<400	No Sep Peak
EC 870	--	--	
Loctite 308	350-500	450-550 (S)	
		450	395 (M)
		530	447 (S)
LP-2		522	455 (VS)
	400-480	550-40 (VS)	
EC 833	250-400	410-490 (S)	
		455	380 (M)
Laminac 4134	320-450 (S)	400-500 (W)	
	365	450 (W)	
		500	380 (VS)
		460	370 (VS)
		440	365 (VS)
EC 1099 (Reflection)	250-350	380-450 (W)	
		400-425	290-350 (VW)

Table 1 (Continued)

Adhesive	Excitation wavelength, nm (Set)	Emission wavelength, nm	Excitation wavelength (observed) nm
EC 1099			
(Microcell in acetone)	250-350	380-500 (S)	
		400-500	310, 360 (M)
		415	310, 360 (W)
(Microcell in toluene)		415	310, 360 (W)
Cascophen R5216		380	310 (M)
	250-300	350-390 (M)	
		365	310 (S)
Penacolite G-1124B		305	220, 265 (W)
		360	250-280 (W)
	200-250	280-380 (M)	

*VS = Very stong fluorescence
S = Strong fluorescence
M = Moderate fluorescence
W = Weak fluorescence
VW = Very weak fluorescence

VS and S would show easily detectable fluorescence.
M would be detectable with some difficulty.
W and VW would not generally be usable.

Table 2

Fluorescence spectra of structural polymers*

Polymer	Excitation wavelength, nm (Set)	Emission wavelength, nm	Excitation wavelength (observed) nm
Celcon Film M9004	200-220	250 (M), 300-550 (S)	
		500	355 (M)
		465	358 (M)
Tedlar	≤230	250, 350, 500 (S)	
		503	210 (W)
		468	200 (W)
		350	220 (VW)
TPX	≤210	465 (W)	
	≤230	260-300, 510 (W)	
	≤250	390 (W)	
		500	210 (W)
Polyethylene fluff 6050	223 (230)	260 (M), 330-380 (S)	
	230 (240+)	330 (S)-380 (W)	
		340, 230 (W)	
CAB	220-310	350 (M)	250, 285 (M)
TFE	≤220	250 (W), 337 (M)	
		485 (M)	
		460	320 (W)
		485	300-400 (W)
	≤210	225, 462 (W)	
		337	220 (W)
Lexan Film	≤260	300 (M)	
	≤370	400 (M)	
		380	290 (M)
Polypropylene	200	465;490 (M)	
	220	340, 526, 250 (M)	
		290 (W)	
	≤240	390 (W)	
		340	222 (W)

Table 2 (Continued)

Polymer	Excitation wavelength, nm (Set)	Emission wavelength, nm	Excitation wavelength (observed) nm
Nylon 12	350-450(385)	450 (S)	
30% glass filled	200-400	440, 470-570 (S)	
Nylon 6-12	No peaks		
33% glass	350-500	500 (M-S)	
		490	380 (W)
Nylon 11	300-350	400 (W)	
		400	No peak
		420	340 (W)
		440	355 (W)
		480	380 (W)
		510	395 (W)
Nylon 6	200-350	400-470 (M)	
		450	350 (W)
		410	340 (W)
Nylon 6-6	300-350	400 (W-M)	
		390	340 (W)
		510	390 (W)
Kel F	None	None	
Mylar	200	260 (M), 525 (S)	
	225	260 (M), 480-560 (W-M)	
Saran F-310	200-450	500-600 (530)(S)	
		570-530	450-225 (W)

*VS = Very strong fluorescence
S = Strong fluorescence
M = Moderate fluorescence
W = Weak fluorescence
VW = Very weak fluorescence

VS and S would show easily detectable fluorescence.
M would be detectable with some difficulty.
W and VW would not generally be usable.

Table 3

Fluorescence spectra of fluorescent pigments*

Pigment	Excitation wavelength, nm (Set)	Emission wavelength, nm	Excitation wavelength (observed) nm
Blue Lawter B5556	320-400	410-430 (M)	
in acetone	360	480 (M)	
	480	540 (W)	
		530	420 (M)
		410-490	390-430 (M)
Gold Yellow	350-490	545-600 (W)	
Lawter 3515		565	345 (M)
in acetone			455 (S)
Red Orange B3513	350-550	595 (VS)	
in acetone		592	330 (W)
			355 (M-W)
			460 (M)
Green B3545	320-400	500 (S)	
in acetone		500	345 (VW)
			460 (M)
Cerise B3530	350-390	595 (VS)	
in acetone		595	350-465
Pink B3522			
in acetone	300-500	588 (M)	
		590	300 (W)
			345 (M)
			400 (M)
			475 (S)
Uvitex OB	300-400	435 (W)	
in toluene		420-450	280-340 (VS)
			408 (VS)

Table 3 (Continued)

Pigment	Excitation wavelength, nm (Set)	Emission wavelength, nm	Excitiation wavelength (observed) nm
PCRP in toluene	310-400	400-440 (W) 420-460	 300-350 (S) 385-400 (VS)

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*VS = Very strong fluorescence
S = Strong fluorescence
M = Moderate fluorescence
W = Weak fluorescence
VW = Very weak fluorescence

VS and S would show easily detectable fluorescence.
M would be detectable with some difficulty.
W and VW would not generally be usable.

Table 4

Fluorescence spectra of solvents*

Solvent	Excitation wavelengths, nm (Set)	Emission wavelengths, nm	Excitation wavelengths (observed) nm
Styrene	300-340	350-410 (S)	
		385	340 (M)
Acetone	260-320	335 (M)	
	300-340	385 (M)	
		390	333 (M)
		330	None
Isopropyl Alcohol (IPA)	220-300	340-440 (M)	
	200-260	290-320 (W)	
		390 (W)	290 (W)
H_2O	220-300	310-340 (VW)	
90% IPA + H_2O	210-270	290-310 (W)	
	210-270	320-360 (M)	
		340	225 (W)
Heptane	200-300	340 (S)	
	260-300	610-650 (W)	
	220	510 (W)	
		330	280 (S)
		625	280 (M)
Toluene	250-350	280-410 (M)	
		330-410	280-290 (M)
	282	330 (S)	
Abs Ethyl Alcohol	200-300	290-350 (M)	
		310	215 (W)
		310	275 (M)
Methyl Alcohol	200-250	295 (S)	
	250-350	350-420 (M)	
	700-350	540-570 (M)	

Table 4 (Continued)

Solvent	Excitation wavelengths, nm (Set)	Emission wavelengths, nm	Excitation wavelengths (observed) nm
2 Methoxyethanol	200-300	600 (W)	

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*
VS = Very strong fluorescence
S = Strong fluorescence
M = Moderate fluorescence
W = Weak fluorescence
VW = Very weak fluorescence

VS and S would show easily detectable fluorescence.
M would be detectable with some difficulty.
W and VW would not generally be usable.

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